DIAGRAMS OF NATURAL PHILOSOPHY.

INTRODUCTION

TO

NATURAL PHILOSOPHY:

Comprising a Popular Account of

THE LAWS OF MATTER AND MOTION,

MECHANICAL POWERS AND MACHINERY;

THE SCIENCES OF

HYDROSTATICS, HYDRAULICS,

PNEUMATICS, ACOUSTICS,

OPTICS, ELECTRICITY,

MAGNETISM, AND CHEMISTRY,

TO ACCOMPANY

REYNOLDS'S SERIES OF

Popular Diagrams of Natural Philosophy,

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LAWS OF MATTER AND MOTION.

As no branch of science can be understood without some previous knowledge of the general properties of matter, it will be desirable to commence by shortly describing them :—

Extension is the bulk of a body, its length, breadth, and thickness.

Impenetrability is that property by which two bodies cannot at the same time occupy one and the same place. If a nail be driven into a block of wood it displaces the particles, but does not become incorporated with them (fig. 1). If in a full glass of water a stone be placed, the water will be forced over to make way for the stone (fig. 2). If we endeavour to fill a phial by plunging it into water, the air will rush out of the phial to make way for the water (fig. 3).

Divisibility denotes the property by which a body is susceptible of being subdivided into an indefinite number of parts. Animalculæ have been found so small that a grain of sand will cover 300,000 of them, each one having a perfect organization ; fig. 4 represents the forms of some highly magnified.

Porosity arises from the influence which heat exercises in separating the particles of matter. The piece of iron B, fig. 6, when cold, will exactly fit into the hole and notch of A ; but if heated it will do neither. Fig. 7 represents the action of heat in expanding and setting in motion the particles of water.

Inertia or **Persistence** is the tendency of matter to preserve its present state, whether of rest or motion, unchanged. Fig. 8 illustrates the first : if the card be struck away the coin will remain balanced on the finger : fig. 9 illustrates the second : a body in motion has a tendency to proceed in a straight line ; but the hare being pursued by a dog, turns quickly, and the latter is irresistibly thrown out of its track and compelled to take a wider turn, thus affording the hare the only chance of escape.

Cohesion is the force by which the atoms of a body are held together in one solid mass. It is greater in some bodies than in others, the solidity or weight of the body corresponding to the cohesive attraction. It is this power which holds the drop of water suspended at the end of the finger, and keeps its minute watery particles united (fig. 10). **Capillary attraction** is another effect of this power which enables liquids to rise above their level in minute tubes (fig .11) Sap ascends in plants by the same force (fig. 12).

Gravitation is that force which causes all bodies on or near the earth to tend towards its centre with a force proportioned to their respective quantities of matter (fig. 13). All bodies attract each other inversely as the squares of the distances. All influences emanating from a central point follow the same law. Fig. 14 illustrates the law in reference to light. At a certain distance the rays illuminate the space A B ; at twice that distance they are spread over C D, four times the former space, but with four times less intensity ; at three times the distance they illuminate the space E F with nine times less intensity, and so on. All bodies possess gravity or weight ; there is no such thing as perfect lightness. Smoke ascends only because it is lighter than the atmosphere (fig. 15). The force of gravity at the surface of the earth is such that in the first second of time, it gives to a body allowed to fall, a velocity of 16 feet ; in the next second 48 feet ; in the third second 80 feet. Fig. 16 shows the rate at which bodies fall ; each of the triangular portions representing 16 feet, the figures on the right, the seconds.

THE CENTRE OF GRAVITY.

The centre of gravity in a body is that about which all its other parts equally balance each other. Figs. 17 to 21 show the position of the centre of gravity in bodies of different forms. The stability of a body resting on the ground depends greatly upon the centre of gravity. The body will stand provided a vertical line drawn from the centre of gravity falls within the base (figs. 22, 24). The mass of rock (fig. 23) will fall because the vertical line falls beyond the base. Bodies having a narrow base are easily upset, for if they are the least inclined their centre is no longer supported, as seen in fig. 25. Rope dancers are provided with a pole, loaded at the ends, for the purpose of bringing their centre of gravity vertically over the rope (fig. 26).

THE PENDULUM.

This body, represented at fig. 27, depends for its motion upon the forces of gravitation and persistence. The longer the pendulum the slower are its vibrations, and, as the length is affected by temperature, various contrivances have been resorted to to correct this expansion and contraction; these are termed *compensation pendulums* (figs. 28, 29). Fig. 30 represents the balance wheel of a watch, with a spring, which is expanded or contracted by the lever C, producing a corresponding effect on the movement of the watch.

CENTRAL FORCES.

These are of two kinds, *centripetal*, or the force of gravity, tending towards the centre; and *centrifugal*, flying from it. The first may be illustrated by a whirlpool at sea, or a whirlwind on land (figs. 31 and 32). Centrifugal force may be illustrated in a variety of ways. If we whirl rapidly a sling with a stone in it, and suddenly set free the stone, it will proceed in a straight line (fig. 33). In turning rapidly a circular grindstone in contact with water, the latter will fly off at right angles (fig. 34). A practical application of this power is seen in the governor-balls of a steam engine (fig. 35). By any increase in the velocity in the engine, the balls are thrown apart, and the levers draw down the collar, D, and with it the end of the lever, F, which thus partially closes the throttle-valve of the steam pipe.

The centripetal and centrifugal forces are sublimely exemplified in the motions of the planetary bodies; the former in their attraction towards the central luminary by gravitation; and the latter in their tendency to proceed in a straight line by the force of persistence.

The velocity of revolving bodies increases in proportion to the distance from the centre of motion. The extremities of the vanes of the windmill move over a much greater space than the parts near the axis, yet describe the circle in the same space of time (fig. 36). In like manner, as our globe turns on its axis, those parts nearer the poles describe smaller circles than those more remote, the equatorial regions describing the largest circles of all, hence, it follows, that the equatorial regions move at a far greater velocity than the regions near the poles (fig. 37).

LAWS OF MOTION.

A body projected by a single force naturally proceeds in the direction of that force; but if in its progress a new force acts upon it, it will then be sent in a new direction. Thus, a ball projected in the line A B C (fig. 38), strikes obliquely the ledge at C, there meeting an obstacle to its progress, which acts as a new force, it is caused to rebound in the direction C D E, making the same angle with the ledge as did the original path of the ball A B C. This effect is commonly expressed by saying that the angle of *incidence* is equal to the angle of *reflection*, the former meaning the angle A B C, and the latter C D E; and this is a law that applies equally to the motions of sound, heat, and light; and therefore, is of the utmost importance throughout physics. If two or more forces act upon a body at certain angles, a single force may be found which would produce the same effect. This single force is called the *resultant* or *equivalent*. In fig. 39 we have an example of this: a ball receiving a blow in the direction A B, and at the same time a blow of equal force in the direction A D, does not pursue either of those directions, but takes a diagonal course between them to C. The effect being the same as if the ball had been sent in the direction A C, by a single force.

The process of finding a single force equivalent to two or more forces is called the *composition of forces*, and the process of finding forces which will produce a motion equal to that of a single force, is called the *resolution of forces*. In fig. 40, this is illustrated in reference to the action of the wind upon the sail of a ship, and of the tide upon the helm. Let A B represent the direction of the wind acting upon the sail E F, placed obliquely to it, then, by drawing A C perpendicular to F E, and by completing the parallellogram D C; the diagonal A B is resolvable into the adjacent sides A C and A D; now, A C being at right angles to E F, will have the effect of propelling the vessel, although not in a straight line; but it may be guided in the desired direction by means of the helm, upon which the water re-acts by the progressive motion of the vessel

MECHANICAL POWERS.

The mechanical powers are essentially but two in number, but are usually considered as six ; namely, the Lever, the Wheel and Axle, the Pulley, the Inclined Plane, the Wedge, and the Screw. The three first are assemblages of levers, and the three last inclined planes. One or more of these powers enters into the composition of every machine.

The Lever consists of an inflexible rod or bar, resting on a support called a fulcrum, for the purpose of raising, by a power applied at one end, a weight at the other. The advantage gained is in proportion to the greater distance of the power from the fulcrum, than is the distance from the fulcrum to the weight to be raised ; thus, if the distance from the power to the fulcrum be five times greater than the distance from the weight to the fulcrum, a force of one pound in the power will balance five in the weight.

There are three kinds of levers ; the *first* kind is that where the fulcrum (F) is placed between the weight (W) and the power, (P, fig. 1). The common balance, (fig. 2) is a lever of the first kind, as is also the Roman steelyard, (fig. 3).

The boy's amusement of see-saw (fig. 4) is another illustration of a lever of the first kind, the bigger boy taking the shorter end of the plank, that his lighter companion at the longer end may balance him.

Fig. 5, shows the application of a lever of the first kind in moving a heavy body ; the nearer the fulcrum to the body to be moved the more powerful being the leverage.

In levers of the *second* kind, the weight is situated between the power and the fulcrum, (fig. 6). This kind of lever is seen in the common wheelbarrow, where the wheel is the fulcrum, the load in the barrow the weight, and the power the man who holds up the shafts. The oars of a boat present another instance ; here the water is the fulcrum against which the blades of the oars press.

Levers of the *third* kind are those where the fulcrum is at one end, the weight at the other, and the power between them, (fig. 7). Here the power acts with a considerable disadvantage, and this kind of lever is only used where the object is to produce great velocity, and which can only be effected by an expenditure of power. The footboard of a common turning lathe affords an example of this kind of lever. But one of the most striking instances of it is seen in the human arm in the act of raising a weight in the hand, when the lower part of the arm becomes a lever of the third kind, the elbow joint being the fulcrum, and the muscles which move the arm, the power (fig. 8). The muscle, by contracting its fibres less than an inch, raises the hand twenty inches ; and if it raises also a weight of twenty-five pounds in the hand, it must act with a force at least twenty times as intense, or of five hundred pounds ; thus showing the extraordinary strength of the living muscle.

Levers may be *combined* in a great variety of ways, and the aggregate effect of such combination is as the product of the effect of the separate levers. Fig. 9, represents a combination of levers of the first kind, in which the power of the small weight P brings down A, which raises B, bringing down C, and consequently raising D ; and thus, if properly supported, will balance the large weight W. By this means a weight of one pound will balance one of a hundred and twenty pounds.

The Wheel and Axle may be considered as a kind of perpetual lever, of which the fulcrum is the centre of the axis, and the long and short arms the radius of the wheel and the radius of the axle, as shown at fig. 10 ; the power P acting upon the weight W, through the intervention of the lever A B, whose fulcrum is the centre of the axle. Supposing the semi-diameter of the wheel to be six times greater than the semi-diameter of the axle, a power of one will balance a weight of six, exactly upon the principle of a lever of the first kind.

There are many modifications of this mechanical power ; one of the most common is the windlass for raising water from a well by means of buckets, (fig. 11). The capstan used on board ships is an upright axle, the moveable bars or levers acting as the wheel (fig. 12). Like the lever, the wheel and axle may be used in combination, the circumference of one wheel acting by means of teeth upon the axle of another, as shown at fig. 13 ; the effect of such combination being similar to that produced by the combination of levers already described.

The compound axle, (fig. 14), is s contrivance by which the power is increased without increasing the diameter of the wheel. This axle has one half of it twice the diameter of the other half. A moveable pulley being attached to the weight to be raised, the rope is passed round the wheel, and coiled in the same direction upon both parts of the axle: upon every revolution of the axle, a portion of the rope equal to the circumference of the thicker part will be *drawn up*, but at the same time, a portion equal to the circumference of the thinner part will be *let down*: hence, every revolution of the cylinder raises the weight through a space equal to half the difference between the circumferences of the thicker and thinner parts of the axle.

The Pulley is a small wheel turning on an axis, and having a groove upon its circumference for the reception of a rope. It is either fixed or moveable. The *fixed* pulley (fig. 15) possesses no mechanical advantage, but is used to change the direction of the power, or to give convenience in pulling.

The *moveable* pulley, however, affords mechanical assistance by dividing the weight. This is illustrated at fig. 16, where the weight of the barrel is equally divided between the part of the rope affixed to the beam, and that held in the hand. Fig. 17 shows tbis more clearly; if the large weight be twenty pounds, ten pounds is borne by A, and ten pounds by P. The fixed pulley, B, is of no other use than to change the direction of the power.

The power of pulleys is increased by their combination. Fig. 18 illustrates this: here the weight is equally distributed between four ropes, consequently it may be supported by a power only a fourth of its own weigbt. Fig. 19 is a system of pulleys, or a *tackle*, as it is usually called, by which a power of one hundred will balance a weight of six hundred. Fig. 20 exhibits a system of pulleys in combination, in which a power of one will balance a weight of sixteen. The power of this system may be greatly augmented by substituting fixed pulleys for the hooks to which the ends of the ropes are attached, in the manner shown at fig. 21. In order to obviate the loss of power occasioned by the friction of the separate axles, where several pulleys are employed, an ingenious arrangement has been resorted to in White's patent pulley (fig. 22), by which all the pulleys in each block turn on the same axis.

The Inclined Plane. It is not difficult to understand that a body may with much greater ease be drawn up a slope, than it can be raised the same height perpendicularly. Hence the advantage of the inclined plane, which acts as a mechanical power, in partly supporting the weight (fig. 23). The longer the inclined space is in proportion to the perpendicular height, the greater is the advantage afforded. Suppose the inclined plane A B (fig. 24), to bear the proportion to the perpendicular height B C, as three to one, then a power of one will balance a weight of three.

Persons have often been struck with astonishment when viewing Stonehenge, how those enormous cross-pieces of stone were raised to the elevation at which we see them, but the mechanical feat is by no means very wonderful, for it would only be necessary to raise an inclined plane of earth in the direction of the line A B (fig. 25), and by means of rollers placed under the stone, pass it to its situation on the top; the earth being removed, the stone would remain secure.

The Wedge is a combination of two inclined planes united at their base (fig. 26). The wedge derives its great power chiefly from the way in which the force is applied—by being struck.

The Screw is a machine of great mechanical power, and is a modification of the inclined plane, as will be seen by reference to fig. 27. The screw has no power by itself, it can operate only by working in spiral grooves corresponding to its threads: these grooves are formed on the inside of a box or nut, through which the screw winds itself. Fig. 28 shows the screw, and its nut, fig. 29, exhibits the screw with a section of the nut, showing the spiral grooves, The power is applied by a lever, the screw, therefore, acts with the combined power of the lever and the inclined plane, thus becoming in reality a compound machine.

Screws are much used in presses of all kinds. The bookbinders' standing press (fig. 30), affords one of tbe best examples of this application of its power.

MOTION AND MACHINERY.

Machines act from the impression of a certain force or power, derived from human labour, that of horses, or from the force of wind, water, or steam; and, in some cases, from that of springs or weights. The motion is usually communicated to a machine in a rotary or circular form, and is, by certain contrivances, diffused through the whole organization, and changed into every conceivable direction. The various parts may also be made to move with any degree of velocity.

Figs. 1 aud 2, represent the ordinary method of transmitting circular motiou by means of endless bands passing over cylinders or drums, the larger drums driving the smaller ones.

Fig. 3, shows the mode of converting, by means of an endless cord or band, the vertical movement of the axis A into the horizontal movements B C and D.

Where circular motion is required to be transmitted in a direction not parallel to the driver, bevel wheels, (figs. 4, 5, 6) are generally used. These are made of various forms, suited to the angles at which they are required to act.

Fig. 7, represents the endless screw, each revolution of which causes the large wheel in which it works to move the space of one tooth. If the wheel therefore have sixty teeth on its circumference, the screw would have to make sixty revolutions for each revolution of the wheel. Circular motion may be converted into rectilinear by means of the wheel and rack, (fig. 8).

Fig. 9, represeuts the eccentric, the use of which is to convert circular motion into reciprocating, or alternate rectilinear motion.

Fig. 10, represents the crank; this is one of the simplest and most useful methods of changing an alternate rising and falling motion into continued circular motion.

In most machines, both the moving force and the resistance to be overcome, are liable to fluctuations of intensity during the working. These are remedied by a reservoir of power, which is usually in the form of the fly-wheel. This wheel is generally formed of iron, the rim being made very heavy; in most cases it is placed in close connection with the original moving force, the effect of which it equalizes in its passage to the machine. The diagram (fig. 11) represents the fly-wheel of a steam engine; it is turned by means of a crank fixed to the axle, and acted upon by the connecting-rod of the beam.

One of the most important chauges of motion that can be effected by machinery is that of converting a reciprocating rectilinear motion into a reciprocating circular one, or vice versa. The common bow used by watchmakers and other artizans, is an example of this, (fig. 12). The bow-string being rolled once round a small wheel carrying the piercer, an alternate rectilinear motion in the bow produces au alternate circular motion in the wheel. The parallel motion of Watt is, however, the most beautiful example of mechanical contrivance for effecting this change. The piston of the steam engine being urged up and down in the cylinder in an exact straight line, and the end of the beam to which the piston-rod has to be attached, moving alternately in a circular arc, it became a difficult problem to connect these in such a manner that a perfectly smooth motion, free from strain, should be imparted from the one to the other. The difficulty was overcome by the arrangement shown at fig. 13.

Fig. 14, represents the universal joint, a simplo and effectual method of transferring rotation from one axis to another. The fusee of a watch affords an example of the beautiful adaptation of the wheel and axle to preserve regularity of action by a *variable* force. The watch derives its motion from the main-spring, (fig. 15) which is wound up by a spindle into a compact form, and the force communicated by the relaxing of the spring, varies in its intensity, being greatest when it begins to relax, and gradually becoming weaker, till its expansive energy is exhausted. To provide for this variation of force, the fusee is arranged into a series of circles A B, (fig. 16) varying in their diameter; at first, when the force of the spring is greatest, the chain acts upon the smallest circle—in other words, it pulls with a small lever, and in proportion as the intensity of the force weakens, and the barrel uncoils the chain from the fusee, and winds it about itself, so does the chain act upon a longer lever. Thus, the gradual diminution of force is counter-balanced by a gradual increase of lever advantage.

An increase of velocity may be obtained by passing an endless band round a large wheel, as A, fig. 17, and then round a small wheel, B. If the diameter of the large wheel be four times greater than the diameter of the small wheel, the latter

will revolve four times for each revolution of the former. The wheel and pinion is another method of effecting this object. It is sometimes necessary that a machine, or part of a machine, should be propelled with a velocity which is constantly changing from fast to slow, and from slow to fast. This is effected by the apparatus represented at fig. 18, consisting of two conically-shaped drums, having their larger diameters in contrary directions; they are connected by a belt, which is so governed by proper mechanism, that it is gradually shifted along from one extremity of the cones to the other, thus acting upon circles of different diameters, causing a continual change of velocity in the driven cone, with relation to that which drives it.

Fig. 19, represents a wheel and pinion. A is a wheel moving on its axis; B is a pinion one-fourth the diameter of the wheel. For each revolution of the wheel, the pinion will revolve four times. By a suitable combination of wheels and pinions a still greater difference in speed may be obtained.

Fig. 20, represents the wheels and pinions for moving the minute and hour hands of a dial. As the hour hand A is required to move twelve times slower than the minute hand B, there is fixed upon the axle of the centre wheel, the cannon pinion C, having ten teeth, in which work those of the wheel D, containing forty teeth; and, therefore, revolving four times slower than C. The minute wheel pinion E, containing twelve teeth, drives the hour wheel F, this wheel is fixed to a bush, revolving freely upon the axle of the centre wheel, and carrying the hour hand, and as the hour wheel has three times as many teeth as the minute wheel pinion, it revolves three times slower, and the minute wheel revolving four times slower than the cannon pinion; consequently, the hour wheel revolves twelve times slower than the centre axle.

Fig. 21, represents a clock. The maintaining power is the weight A, acting by the cord upon the barrel B, to which is attached a large wheel giving motion to the pinion C, which carries the minute hand; while the pinion D gives motion to the hour hand. The division of minutes and hours being thus obtained; the next step is to regulate the motion of the train of wheels and pinions; this is effected by the escapement, consisting of the wheel E and balance F. The pallets G G, are intended alternately to take the teeth of the wheel in which they act; this produces the ticking sound so audible in every species of clock. The balance F continually oscillates to and fro, and by its slow regular motion, gives uniformity to the operation of the wheel work of the clock.

Fig. 22, represents the common clock escapement wheel and pallets, the pendulum being connected with the verge of the latter by means of a bent wire.

Fig. 23, represents the escapement of a lever watch, in which the impulse is given to the balance by a lever attached to anchor pallets.

Fig. 24, exhibits the principal parts of a corn mill. On the shaft of the water wheel, from which the motion is derived, is fixed a cog-wheel, A, which acts against the upright staves of the trundle B, driving it round, and with it the upper millstone, which is fixed to the top part of the spindle C, the spindle passing through a hole in the centre of the lower millstone. D E is a round box enclosing the millstones, with an aperture at the top, through which the corn from the hopper F, passes down between the stones; the supply being regulated by means of the shoe G, so adjusted by the line H, as to enlarge or diminish the opening at the bottom of the hopper.

Fig. 25, represents a machine for printing newspapers, &c. It prints both sides of the sheet during its passage through the machine, and is capable of throwing off one thousand sheets per hour. The mode of operation is as follows: the damped paper being piled upon a table, A, a boy standing on the adjoining platform takes up one sheet after another, and lays them upon the feeder B, which has several linen girths passing across its surface, and round a pulley at each end of the feeder, so that when the pulleys begin to revolve, the motion of the girths carries forward the sheet, and delivers it over the entering drum C, where it is embraced between two series of tapes that pass round a number of tension rollers. The paper is thus conducted under the first printing cylinder D, to the second cylinder E, and passing under which, it is then received completed by a boy. These two great cylinders are made of cast iron, turned perfectly true; they are covered in those parts corresponding to the typographic impression with fine woollen cloth. The drums F and G, are made of wood; and serve to conduct the sheet evenly from one printing cylinder to the other.

HYDROSTATICS.

This department of science treats of the pressure and equilibrium of liquids, the most remarkable property of which is, that of *equality of pressure*. This property arises from the extreme minuteness and independent gravitation of each of the particles, and from the manner in which they act upon each other; being arranged, not perpendicularly one above the other, but obliquely, as shown at fig. 1. One particle above pressing between two particles beneath, the latter consequently sustain a lateral pressure, just as a wedge driven into a piece of wood separates the parts laterally. This lateral pressure is the result, therefore, of the pressure downwards, or the weight of the liquid above.

Fig. 2 illustrates the different degrees of force with which water flows from apertures in a vessel at different heights. Fig. 3 represents part of a teapot, which we suppose to be filled with columns of particles of water; the particle 1, at the bottom, will be pressed laterally by the particle 2, and thus be forced into the spout, where, meeting with the particle 3, it presses it upwards, and this pressure will be continued till the water in the spout has risen to a level with that in the pot.

Fig. 4 is another illustration of the upward pressure of water. A is a glass tube, widened at the lower end, against which, by a string passing up the tube, a thick piece of metal is held close by the hand. Upon immersing the glass and plate thus held together in the water to a certain depth, the hand may be withdrawn from the string, the upward pressure of the water being sufficient to support the piece of metal.

Several interesting illustrations can be offered to prove the remarkable fact, that the pressure of water on the bottom of the containing vessel does not at all depend on the quantity of water, but upon the size of the base and the perpendicular height at which the water stands.

Figs. 5 and 6 represent two vessels of precisely similar capacities, and each containing the same quantity and weight of water, but which have very different pressures upon their bottoms; that upon C D being less than the absolute weight of the water, viz., the weight only of the cylindrical column, A B C D; while that upon G H is more than the absolute weight of the water, viz., the weight of a cylindrical column, E F G H, for the water in the central column G H I K, presses laterally with the same force, as it does on the part on which it stands; and thus an uniformity of pressure is exerted over every part of the bottom.

Fig. 7 illustrates the latter case still more strikingly: F is a tube communicating with the chamber, E E, and on these being filled with water, the pressure upon the bottom, C D, will be precisely the same as if the whole space, A B C D, were filled with water.

Fig. 8 represents the hydrostatic bellows, which has been contrived to exemplify the great effect of a column of water. The tube A communicates with the interior of the bellows, and upon these being filled with water, the upper board, B will be raised, and enabled to sustain a very considerable weight; for if the tube A hold but an ounce of water, and have an area equal to the thousandth part of the area of the top of the bellows, the ounce of water in the tube will sustain a thousand ounces placed on the bellows.

Another important principle in reference to liquids is their tendency to seek an uniform level. If we pour water into a bent tube, as fig. 10, it will stand at as equal height in both limbs.

If there be two tubes or limbs of a tube connected together, however different their width or form may be, a liquid poured into them will stand at the same level in both, and thus a portion, however small, will balance a portion, however large, as shown at fig. 11.

Fig. 12 represents a number of vessels of different forms fixed in the vessel A B, so as to communicate with it, and by means of it with each other. Water being poured into any one of them will stand at the same level in all, as shown by the line, C C.

From these considerations, a most important conclusion follows, namely, that water will, by being confined in pipes or close channels, rise to the height from whence it came; and upon this principle depend all the useful contrivances for conveying water into towns and houses by pipes from distant reservoirs. References to figs. 13 and 14 will illustrate this more clearly.

Fig. 15 represents the water level, and fig. 16 the spirit level.

Intermitting Springs.—Those springs which flow and stop by regular alternations may be accounted for upon the principle of the syphon, represented at fig. 17. If this tube be filled with water, and the shorter leg be plunged into a vessel of water, the water will flow up the tube, over the bend, and out at the longer leg, till the vessel is emptied.

Fig. 18 represents a section of a hill, having within a cavity, A, from which runs a channel in the form of a syphon; the rain falling upon the hill, precolates through the crevices and pores, *d d d*, and in course of time will fill the cavity with water up to the level, E E; it will then flow over the bend, B, and continue to flow and supply the spring till the level of the water falls below the mouth of the channel, when the action of the syphon will cease, until, by fresh supplies, the level of the water is again raised, so as to flow over the bend, when the syphon will act as before.

The Hydrostatic Press.—Fig. 19. This is perhaps the most powerful machine ever invented, the only assignable limits to its power being the strength of the materials of which it is formed. A is the force pump, by the action of which water is forced through the small tube, B B, and its pressure communicated to the mass of water in the cylinder, C, there the water in its endeavour to resist compression forces up the moveable piston, D D, with its burden, and the action of the pump being continued, the pressure is gradually increased until the required degree is produced.

Fluid Support—Specific Gravity.—A solid body immersed in a fluid displaces exactly its own bulk of fluid, and the force with which the body is buoyed up, is equal to the weight of the fluid which is displaced; therefore, the body will sink or swim, according as its own weight is greater or less than the bulk of the displaced fluid. This refers to bodies of less density than water. Any body of greater density than water, when wholly immersed in that fluid, loses exactly as much of its weight as the weight of an equal bulk of the water which it displaces.

These laws are of much importance, as an acquaintance with them enables us to explain innumerable phenomena in nature, in reference to the floating of bodies in water, or in the atmosphere.

Fig. 20 is a vessel of water, and A a solid body of the same density immersed in it, and which, being equally pressed upon from above and below, retains its position, just as the mass of water it has displaced would have done. But if a solid body as B, fig. 21, heavier than water, bulk for bulk, be placed in it, it will sink to the bottom; while a body lighter than water will float on the surface partially immersed, as A, fig. 21, the weight of the water displaced being equal to the weight of the whole solid. Thus, the weight of any floating body may be ascertained by measuring the quantity of water which it displaces.

Fig. 22 represents the hydrostatic balance used for ascertaining the specific gravity of solid bodies, which are suspended in water by a horse-hair attached to the bottom of the scales.

Hydrometers.—These are instruments which, being immersed in liquids, determine the proportion of their densities, or specific gravities, and thence their qualities. The use of the hydrometer depends on the following propositions:—1. The hydrometer will sink in different fluids in an inverse proportion to the density of the fluids. 2. The weight required to sink a hydrometer equally far in different fluids will be directly as the fluids. Each of these two propositions gives rise to a particular kind of hydrometer; the first with the graduated scale, as fig. 23, the second with weights, usually hollow glass beads of various weights, which are dropped into the liquid till one is found to remain stationary, indicating the density of the liquid.

Fig. 24, represents Nicholson's hydrometer, consisting of a hollow copper ball A, with a steel stem B, supporting a small dish C. By the successive addition of weights to the dish C, the instrument may be sunk so as to obtain the complete range of specific gravity.

Fig. 25, represents the areometer, an instrument for determining the relative specific gravities of any two fluids which may be poured together without mixing, as mercury and water, oil and water, &c.

HYDRAULICS.

THIS science, which may be considered a branch of hydrostatics, treats of liquids in motion.

The particles of liquids flow over and amongst each other with less friction than over solid substances, and all the substances gravitate independently. If a hole be made in the bottom of a vessel the liquid will flow out; those particles directly over the orifice being discharged first, their motion causes a temporary vacuum, into which the particles tend to flow from all directions; and thus the whole mass of the water is set in motion (fig. 1). As water flows through bended pipes to the same level from whence it proceeds, it enables us to form jets or fountains (fig. 2). If, for example, a body of water be collected in a reservoir on the upper part of a house, and a tube descending from it to the garden be made to turn upwards, having a very small bore, the water will spurt up in a jet to nearly the same height as the surface of the water in the reservoir. It will not rise quite so high on account of the resistance of the air, and the effect of gravitation. Most of the ornamental fountains in public gardens are formed upon this principle.

Pumps and Machines for Raising Water.—These may be divided into four classes. First, those machines in which water is lifted in vessels by the application of some mechanical force to them. The earlier hydraulic machines were constructed on this principle; such as the Persian wheel (fig. 3), consisting of upright buckets attached to the rim of a wheel moving in a reservoir of water; the buckets are filled at bottom as they pass through the water, and emptied at top; the water is thus raised to a height equal to the diameter of the wheel. The Archimedean screw (fig. 4), and the chain pump (fig. 5), are modifications of the same principle.

The second class of machines are those in which the water is raised by the pressure of the atmosphere, and comprises all those machines to which the name of pump is more particularly applied. These act entirely by removing the pressure of the atmosphere from the surface of the water, which may thus be raised to any height not exceeding thirty-two feet.

Fig. 6 represents the common pump, which consists of a cylinder, with an air-tight piston, having a valve, A, opening upwards. When the piston is raised a vacuum is raised in the tube beneath, which is immediately occupied by the water; on depressing the piston, the water passes through the valve, A, in its centre, and on being raised, the water is lifted to the top of the barrel, and flows through the spout. To prevent the water returning to the well when the piston is depressed, a valve (B) opening upwards is placed near the bottom of the pump.

When it becomes necessary to raise water to a greater height than thirty-two feet, the third class of machines, or those which act by compression on the water, usually by the intervention of compressed air, are employed. All pumps of this description are called *forcing pumps*, and by these water may be raised to any height by applying sufficient force.

Fig. 7 represents the forcing pump, consisting of two parts, or barrels, one similar to the common pump, and the other rising by its side. The water is first raised in the former part in the same manner as in the common pump, excepting that the piston has no opening valve, but is solid, and the air is forced out through the valve, A, into the adjoining barrel. Through this valve the water is also forced, and the pressure of the descending piston causes it to flow up the ascending pipe and issue out of the top. The vessel in which the lower end of the ascending pipe is placed, encloses a volume of air; when the water rises this air is compressed, and being elastic it re-acts upon the water, thus causing it to flow upwards with greater force.

The fire-engine is an interesting example of the utility of this machine; its principle will be readily understood by reference to fig. 8. A is the suction-pipe by which water is supplied from the street main; B B are two valves opening upwards into the barrels of two forcing pumps, containing solid pistons; from the lower sides of the pump-barrels proceed force-pipes, which communicate with an air-chamber, C C, by valves, D D, opening upwards into it. Through the top of the air-chamber descends nearly to its bottom a pipe, E E, to the upper part of which is attached the hose for directing a stream of water on the fire. By the alternate action of the pistons, water is drawn through the valves B B, and

propelled through the forcing valves, D D; and the enclosed air being compressed, re-acts upon the water, which is projected up the centre pipe and along the hose with a force proportioned to the power applied to the pistons by the persons who work the engine.

The fourth class of hydraulic machines for raising water consists of such engines as act either by the weight of a portion of the water which they have to raise, or of the water, or by its centrifugal force, momentum, or other natural powers. The centrifugal pump (fig. 9) belongs to this class. This machine raises water by means of the centrifugal force, combined with the pressure of the atmosphere. A B is an upright spindle, so fixed that rapid rotary motion may be communicated to it by a wheel and pinion, or winch. C D, C D, represent any number of curved pipes so disposed and fixed to the spindle that their lower ends may be near to it, and be covered by the water to be raised, and their upper ends to be extended to a considerable distance from the centre of motion, and bent downwards to prevent the scattering of the water. Before putting the machine in action the several pipes must be filled with water, which will be retained in them by a valve near the bottom opening upwards. The machine is then put in motion by turning the spindle rapidly. The upper ends of the pipes will describe a much larger circle than the ends below, and, consequently, such a centrifugal force will be generated at the upper ends as will produce a vacuum, and the water below will then rise and flow from the upper ends of the pipes into the circular trough, whence it may be delivered by a pipe as required.

Power to be derived from Water.—Motion is generally obtained from water either by exposing obstacles to the action of its current, as in water-wheels, or by arresting its progress in moveable buckets or receptacles, which retain it during its descent. A water-wheel consists of a hollow cylinder or drum, revolving on a central axle, from which the power is communicated; while the exterior surface is occupied by float-boards, or cavities upon which the water is to act. Water-wheels are divided into three classes—first, the *Undershot* wheel (fig 10), having floats dipping into the water, the current of which, acting against them, causes the wheel to revolve. The second class are those termed *Overshot* wheels (fig 11), in which the circumference is occupied by a series of cavities, into which the water falls from above; as the wheel revolves these cavities become inverted and discharge their contents at the bottom of the wheel. This description of wheel is much more powerful, as well as much more economical in its consumption of water, than the preceding. The third kind of water-wheel is that termed the *Breast* wheel. In this the water is delivered about half-way up it, or rather below the level of the axis, and the brickwork upon which the water descends is built in a circular form, so as to make it parallel to the edges of the float-boards of the wheel; its arrangement and mode of action will be readily understood by reference to fig. 12.

Fig. 13 represents Barker's mill, a machine which owes its efficacy to the centrifugal force. It consists of a long cylindrical pipe, having a funnel at A, and terminating in a pivot, turning in a socket, at B. About A is an axis C, passing through a frame, and carrying with it the upper millstone. At the bottom of the pipe at B, is a cross pipe, D E, at the opposite sides of which are two apertures, from which the water poured into the funnel at A, spouts with considerable velocity, and, from the resistance of the air, gives motion to the machine.

PNEUMATICS.

This branch of science treats of the nature and properties of the atmosphere and of their effects upon solid and fluid bodies. The atmosphere is a thin gaseous substance, which envelopes the earth on every side to the height of about forty-five miles, its density decreasing with its height. Fig. 1, represents the atmosphere, which is divided by lines into thirty spaces, each of which contains the same quantity of air, the lower layers being so much compressed by the weight of those above them, that the lower half of the atmosphere lies within about three and a half miles of the earth's surface, while the upper half is so expanded as to occupy upwards of forty miles. The upper thirtieth part alone occupies more space than all the remaining thirty-nine parts.

Mechanical Properties of Air.—The most essential point in which air differs from other fluids is by its elasticity; that is, its power of increasing or diminishing its bulk, according as it is less or more compressed. Air possesses the universal properties of matter. Its impenetrability may thus be shown: Fig. 2, is a vessel partly filled with water, upon the surface of which floats a small cork; fig. 3 is a smaller cylindrical glass vessel, with a stop cock, which is closed. If this vessel be inverted over the cork, as at fig. 4, and its mouth pressed into the water, it will be found that the water will not enter the inverted glass, except to a very limited height, owing to the air in the glass excluding the water; but if the stop cock be opened, the air will escape, and the water rise to the same level within as it is without the glass.

That air is inert and moveable, we have many and familiar proofs, as the resistance it offers to a body passing through it, and the force exerted by the wind. It also possesses weight, one hundred cubic inches weighing about thirty-one grains.

Laws of Air.—First, the pressure of the air is equal in all directions; second, its degree of pressure depends on the vertical height, and is in proportion to its density, and to the weight of the fluid displaced.

That air presses in all directions may be proved by filling a bladder with that fluid, and then pressing upon it; the pressure will be freely communicated through the mass, and the confined air will rush out with equal force at whatever part a hole is made in the surface.

The pressure depending on vertical height or depth of air, is an important property of the atmosphere, and on it depends the explanation of numerous phenomena.

Air being a substance possessing gravity, necessarily presses downwards in the direction of the centre of the earth; and, therefore, the degree of pressure on any given point will be equal to the weight of the column of air above that point, and proportional to its density. The atmosphere is of the greatest vertical height at the level of the sea, and here its pressure is about fifteen pounds on every square inch of surface. The pressure being exerted upwards sideways, obliquely, and in every other direction, as well as downwards.

Some illustrations may be given of the pressure of the air. Figs. 5 and 6 represent two hollow hemispheres of brass; these being placed in contact and the air withdrawn from the interior, the external air will exert a pressure of 15 lbs. upon every square inch of their surface, so that if two persons pull the handles in opposite directions they will be unable to separate the hemispheres. The common leather sucker (fig. 7) with which boys raise stones, acts from the pressure of the atmosphere. It is the pressure of the atmosphere which causes liquids to rise in pumps and syphons.

The Barometer. This instrument consists of a column of mercury, supported in a tube by the pressure of the atmosphere, and therefore indicating that degree of pressure (fig. 8). It is formed by a glass tube about 34 inches long, closed at one end and open at the other. The tube being filled with mercury, the open end is stopped with the finger to prevent any running out, and the tube being inverted, the open end is placed in a small cup of mercury, and the finger being withdrawn, the mercury in the tube now subsides three or four inches, above the top of which in the tube is a perfect vacuum. The tube being then fixed to a graduated frame, we have a barometer. The mercury will stand in the tube at the height of from 28 to 30 inches, according to the state of the air; and the reason of this is, that the pressure of the whole atmosphere will not raise

a column of mercury higher than about 30 inches; that is, a column of air equal to the height of the atmosphere, from the level of the sea, is of the same weight as a column of mercury 30 inches high, the one thus balancing the other. The figures at the sides of fig. 1, show the height of a column of mercury at different elevations: the barometer thus becomes an important means of determining the altitude of mountains.

The wheel barometer is represented at fig. 9. The tube is closed at the top, and bent upwards at its lower extremity, which is open, and the mercury buoys up a small float, F, to which a thread is attached, passing over a pulley and terminating in the little ball, W. The friction of the thread on the pulley turns an index which points to the words on the dial plate.

When the mercury falls in the barometer, an indication is given of diminished pressure; and as this causes the air to expand and become sensibly cooled, moisture is likely to be precipitated in the form of rain.

The Air Pump.—Air may be artificially withdrawn from a containing vessel by means of an apparatus called the air pump, represented at figs. 10 and 11 (the latter showing the pistons and valves). A is the receiver, resting in close contact with the pump plate B, near the centre of which is the open end of the tube C C, communicating with the exhausting barrels D D, these are fitted with pistons having valves opening upwards, so as to allow the air beneath to pass out but preventing its return. At the bottom of the barrels are two other valves also opening upwards, admitting the air from the tube into the barrels when the pistons are raised, and on their descent preventing its return; the air thus confined in the barrel, by the descent of the piston, becomes compressed, and forcing open the valve in the piston, escapes into the open air. The pistons are connected by a rack and pinion movement with a handle, and are raised alternately, thus producing a vacuum beneath the receiver. By means of the air pump many interesting experiments in pneumatics may be performed. When the air is thoroughly exhausted, light and heavy bodies fall with equal swiftness: most animals die immediately; vegetation stops; combustion ceases; gunpowder will not explode; heat is slightly transmitted; a bell sounds faintly; magnets are powerless; glowworms give no light; and watery and other fluids turn to vapour. We thus see the important uses of the air in supporting life, vegetation, and combustion; in forming a medium for conveying to us the sound of each others voices; besides contributing in numberless ways to our comfort and enjoyment.

Air Condenser.—Fig. 12 represents a section of the condensing syringe, having an opening at A to admit the air, and a valve at B opening downwards. The air being forced by the piston through the valve B, is prevented from returning by the form of the latter. Fig. 13 represents a vessel partly filled with water. By means of the condensing syringe, a large quantity of air may be forced through the tube into the space A A; the stop cock being then closed and the syringe detached, and the stop cock being again opened, the pressure of the air upon the surface of the water will force it up in the form of a jet d'eau. The elastic force of compressed air is very great, and is sometimes employed for the projection of balls from the air gun (fig. 14).

Air Balloon.—The air balloon (fig. 15) is a light silken bag of large dimensions, filled with a gas, which bulk for bulk, is lighter than air, so that, when inflated, the machine becomes lighter than the air which it displaces. and this difference is so considerable that it is enabled to carry up with it several persons in a car attached. As it ascends, the air becoming less dense, the difference between its weight and that of the air displaced is gradually diminished, until it attains such a height that the air it displaces is so rare, as to be only equal in weight to the balloon; this, therefore, becomes the limit of its ascent. In order to descend the bulk of the balloon is diminished, by the gas being allowed to escape by opening a valve; thus, the weight of the balloon is made to exceed that of an equal bulk of air and it accordingly falls.

The Diving Bell.—Fig. 16. This machine is formed of iron, and is usually capacious enough to hold three or four persons. It is constructed on the impenetrability of air, before described. Air is pumped in from above by means of a forcing air pump,or condenser; the water is thereby prevented from rising in the machine, and the persons within are enabled to breathe freely. A represents the pipe conveying the fresh air from force pumps, and B the pipe conveying th vitiated air from the bell.

ACOUSTICS.

Acoustics is the science of sound and hearing. If a bell (fig. 1) be struck by its clapper, the body of the bell vibrates, and in its agitation beats or makes impulses on the air, which, yielding under the stroke, is compressed or condensed to a certain distance around. The compressed air instantly expands, and in doing so repeats the pressure on the air next in contact with it; and thus each of the original strokes of the vibrating metal sends out a series of shells of compressed air, somewhat like the waves dispersed over a lake from the dropping of a stone into its calm surface. The air thus agitated, finally reaches the ear, where it gives a similar impulse to a very fine membrane, and the mind then receives the idea of sound.

Sound travels at the rate of 1,125 feet per second, advancing with undiminished velocity, but with unequal intensity. It thus travels a mile in little more than four seconds and a half, or thirteen miles in a minute; the softest whisper and the loudest thunder travelling with equal velocity. The intensity of sound increases or diminishes with the increase or decrease of the elasticity of the air. Hence, in proportion as the air is rarified, sound loses its force.

An echo, or duplication of sound, is one of the most interesting phenomena in acoustics. The cause of it is precisely analogous to the reaction of a wave of water striking the precipitous bank of a river, it is thrown back in a diagonal direction to the side whence it came, and there again strikes on the bank. In the same manner, the pulses or waves of sound are reflected or thrown back from flat surfaces which interrupt them, and thus returning, produce what we call an echo. An echo may be donble, triple, or quadruple, according to the nature and number of the projecting surfaces from and to which the sound is allowed to play. One of the most interesting echoes of this kind in nature, is that which occurs on the banks of the Rhine at Lurley. The report of a pistol fired on one side, is repeated from crag to crag on the opposite sides of the river, as represented at fig. 2.

The concentration of sound by concave surfaces produces many curious effects. The whispering gallery of St. Paul's, London, affords an example in illustration. Fig. 3, represents the circular dome, S the speaker, and H the hearer. Now as sound radiates in all directions, a part of it will proceed in a straight line from S to H, while the other rays of it will proceed from S to A A, S to B B, etc.; but the ray that impinges upon B B, will be reflected to H, and that which strikes at A A, will be reflected to B B, and from thence to C C, and on to H; and so of all intermediate rays. Consequently, the sound at H will be much stronger than if it had proceeded immediately from S, without the assistance of the dome.

Fig. 4, represents a speaking trumpet. These instruments are constructed on the principle of the reflection of sound. The voice, instead of being diffused in the open air, is confined within the trumpet; and the vibrations which spread and fall against the sides of the instrument are reflected according to the angle of incidence, and the rays (distinguished by the dotted lines) are brought to a focus at F, at which point the sound is prodigiously increased. Fig. 5, represents the hearing trumpet, which acts upon the same principle. Acoustic tubes, represented at fig. 6, are used for conveying messages from one apartment to another at a distance.

The Ear.—The mechanism of hearing is beautifully adapted to the purposes of life. From the external part of the ear, (fig. 7) proceeds a tube leading into the head, and the sounds collected and concentrated at the bottom of this tube, fall upon a fine skin or membranc, A, called the membranum tympani, which is extended over the circular opening of the bottom of the tube. Behind this membrane is a curious chain of four small bones, B, C, D, E, forming a communication between the membrane and a circular opening called the foramen ovale, F. The next division of the ear is called the labyrinth, and consists of the cavity G, of the semi-circular canals H, and of the cochlea I. Over this complex inner compartment, which is filled with water, the nerve of hearing is spread as a lining. The action of the principal parts is as follows: the pulsations of the air are impressed upon the membrane, causing it to vibrate. These vibrations are continued through the agency of the chain of bones to the foramen ovale, when they are received by the nerve, which transmits the sensation to the brain.

Musical Sounds.—There is a peculiar character in sounds, depending on the character of the sounding body. A blow with hammer, or the report of a pistol, produces only a noise. But if a body be of such a thinness and lightness as to produce a succession of impulses of a sufficient degree of quickness, a *tone* is the

result; namely, a sound composed of a great number of noises all so close upon each other, that they bring but one result to the ear. In a *noise*, or unmusical sound, the waves follow each other like those of the sea, with no regularity either in their intervals or intensities. The more regular they are, the more clear or musical is the sound.

The principal sounds in music are only seven in number. The notes are of different degrees of shrillness, one rising above another in succession; they are named do, re, mi, fa, sol, la, si, or by the first seven letters of the alphabet, as represented at fig. 8.

The frequency of vibrations on strings increases with their shortness, lightness, and tension. Fig. 9, illustrates the vibrations of a string, A B, which is made fast at both ends, and being drawn on one side to C, it will not only return to its original position, but proceed onwards to D. This is its first vibration; at its termination, the string will again tend to return to its natural state, A B, and it will therefore return to that line, and pass on beyond it to E, and thence back again to F, then in the same manner to G and H; the resistance of the air continually lessening the motion till the whole is destroyed, and the string comes to rest in its original position. The vibrations, whether large or small, are performed in equal times.

If a common violin string be extended between two points on a board, and screwed up, it may be made, according to its length and degree of tension, to vibrate when struck exactly 240 times in a second. The note which it thus produces is C or do; and a person, on trial, will find that this is the note with which he is most apt to begin a song when he attempts to sing. The note in his voice will be perfectly in unison with the note produced by the string, that is, they melt into and agree with each other, and the effect will be pleasant. This is because the membrane at the top of the singer's windpipe vibrates exactly the same number of times in a second producing that note, as the string does. Thus, the same note produced on any musical instrument is due to the same number of vibrations per second, and, however different the quality of these notes, as given by different instruments may be, they all agree in *pitch*, and this is determined by rapidity of vibration. By shortening the string we increase the number of vibrations per second in the same ratio inversely, so that if the string be shortened one half, its vibrations will be doubled, giving a note an octave higher than the preceding one, and in this way all the different notes may be produced.

Musical Instruments.—These are usually divided into three distinct classes, namely: first, stringed or membranous instruments, as the harp, drum, &c.; secondly, wind instruments, as the organ, French horn, flute, &c.; thirdly, metallic instruments, as bells, cymbals, musical boxes, &c.

The action of the hand upon the harp, the bow upon the violin, the fingers upon the tambourine, or the sticks upon the drum, all cause vibration. The sound produced does not in the first instance arise from the vibrations acting upon the external air, but in the constriction of the atmospheric particles interspersed within the elastic animal fibre, and these particles thence expanding into the surrounding air, originate the production and diffusion of sound. Where the elasticity is destroyed by damp, motion is produced without occasioning sound, as in a wet drum head.

With respect to the sounds produced by wind instruments. The effect is caused by the vibrations of a column of air confined at one end, and either open or shut at the other; the length of the sounding column determining the nature of the vibrations. In the flute, clarionet, bassoon, &c., into which the air is propelled in nearly an equable manner, harmony is occasioned by opening and closing apertures in the side, thus dividing the whole column of air into regular portions. In such instruments as the trumpet, horn, &c., the harmony is propelled by the mouth and lips, the metallic surfaces merely deepening the intonation. In organs, each tube is constructed to utter a separate note, and the harmony is produced by opening or shutting the tubes at pleasure by the action of keys.

Metallic instruments, as bells, are dependent upon their composition and relative size for their diversity of tone. The notes of musical boxes are regulated by the length and thickness of their springs. In all these instances it will be observed that the same principle prevails of a constrictile power being first produced, which afterwards leads to that modified expansion which creates sound, tone, and harmony.

OPTICS.

Optics is the science of light and vision.

All visible bodies may be divided into two classes—*self-luminous* and *non-luminous*. The first comprise those bodies which shine by their own light, as the stars, sun, flames, &c. Non-luminous bodies are those which have no power of discharging light of themselves, but which throw back the light that falls upon them from self-luminous bodies. Light emitted from a self-luminous body is projected in straight lines in every possible direction, so that the luminous body not only seems the general centre whence all the rays proceed, but every point of it may be considered as a centre which radiates light in every direction (fig. 1). A ray of light is a straight line of light projected from a luminous body, and a pencil of rays is a collection of rays proceeding from any one point of a luminous body (fig. 2).

When rays of light meet with an opaque body through which they cannot pass, they are stopped short in their course, and cause the opaque body to form a shadow on the other side of it. If the luminous body (as A, fig. 3) be larger than the opaque body (B), the shadow will gradually diminish in size till it terminates in a point; if smaller, the shadow will increase in size, as it is more distant from the object that projects it (fig. 4). A number of lights in different directions, while they decrease the intensity of the shadows, increase their number, which corresponds with that of the lights (fig. 5).

Reflection of Light.—When a ray of light falls perpendicularly on an opaque body, it is reflected back in the same line towards the point whence it proceeded; if it falls obliquely, it is reflected obliquely, but in the opposite direction, the angle of reflection being equal to the angle of incidence (fig. 6).

The principle of reflection may be illustrated by the case of a plane mirror or looking glass (A B. fig. 7). The ray from the eye of the spectator at C will be reflected in the same line C A; but the ray D B, coming from the foot, in order to be seen at the eye, must be reflected in the line B C, and therefore the foot will appear behind the glass at E, along the line C B E.

There are three kinds of mirrors used in optics; the plane or flat, the convex, and the concave. A convex mirror has the peculiar property of making the reflected rays *diverge*; and a concave mirror makes the rays *converge*.

M N, fig. 1, represents a convex mirror formed of a portion of the exterior of a sphere, whose centre is O. A B C are three parallel rays, the middle one of which only is perpendicular to the centre of the mirror, and is reflected in the same line; the two others falling obliquely, will be reflected obliquely to G and H, the dotted lines, P P, being perpendiculars which divide their angles of incidence and reflection. By continuing the reflected rays G B and H E, backwards, they will meet at F, their virtual focus behind the mirror.

If A B, fig. 9, be an object placed before the convex mirror (M N), and lines be drawn from its extreme points A B, to O, the centre of the sphere, a diminished representation of the objects will be formed at the focus.

Fig. 10 illustrates the property of a concave mirror. A B C are three parallel rays, which, striking the mirror, are reflected, the middle ray in the same line, and the two others converged so as to meet at the focus F, midway between the surface of the mirror, and the centre of its concavity C. The dotted lines P P, are perpendiculars.

Images reflected from concave mirrors appear larger than the real objects, provided these objects are within the focus, as A B, fig. 11.

A B, fig. 12, is an object placed at some distance in front of a concave mirror. In this case, a small and inverted image of the object will be formed at D E. When the object is placed at D E, a magnified representation of it will be formed at A B.

Concave mirrors are used as burning glasses (fig. 13).

Refraction of Light.—Refraction is the effect which transparent mediums produce on light on its passage through them. Opaque bodies *reflect* the rays; transparent bodies *transmit* them; but it is found that if a ray, in passing from one medium into another of different density, fall obliquely, it is turned out of its course, or *refracted*; but if it fall perpendicularly it is not refracted, but proceeds through the new medium in its original direction.

Let fig. 14, be a vessel half filled with water. If a ray strike it in the perpendicular direction, A B, it will be continued in the same line to C; but if a ray be admitted at D, it will strike the water obliquely at B, when it will become subject to two opposite forces, the attraction of the water endeavouring to draw perpendicularly to C, and the projectile force of the ray inducing it to proceed

in its original direction to F; the consequence will be, that it will pursue an intermediate course to E.

If a coin be placed in a basin, so that on standing at a certain distance it be just hid from the eye of an observer by the edge of the basin, and then water be poured in by a second person, the first keeping his position, as the water rises the coin will become visible, and will appear to have moved from the side to the middle of the vessel (fig. 15).

These facts lead to an important axiom in optics; namely, that we see everything in the direction of that line in which the rays approach us last. Hence, the sun is seen several minutes before it comes to the horizon, and as long after it has sunk beneath it, because its rays strike first upon the atmosphere, and are by it refracted, or bent towards the earth (fig. 16).

In passing through a pane of glass the rays suffer two refractions, but which, being in contrary directions, produce nearly the same effect as if no refraction had taken place. A A, fig. 17, represents a thick pane of glass seen edgeways. When the ray B approaches the glass at C, it is refracted to D; at that point, returning into the air, it is again refracted, but in a contrary direction, and in consequence proceeds to E. But this is the case only when the two surfaces are parallel to each other; if they are not, the two refractions may be made in the same direction. Thus, when the parallel rays (fig. 18) fall on a piece of glass having a double convex surface, that ray only which falls in the direction of the axis of the lens is perpendicular to the surface; the other rays falling obliquely are refracted towards the axis, and meet at a point beyond the lens, called its focus.

Figs. 19 to 23 represent sections of lenses of various forms, having different refractive properties. The property of those which have a convex surface is to collect the rays of light to a focus; and of those having a concave surface to disperse them. The rays falling on the concave lens, fig. 25, will each be attracted towards its thicker extremities, both on entering and quitting it; and will, therefore, by the first refraction be made to diverge to A C, and by the second to *d e* The ray B, falling perpendicularly on the axis of the lens, suffers no refraction.

Lenses which have one side flat, and the other convex or concave, as figs. 19 and 20, are called plano-convex and plano-concave. The focus of the former is at the distance of the diameter of the sphere, of which the convex surface of the lens forms a portion, as shown at fig. 26.

Fig. 24 represents a section of a prism, the principal use of which is to enable us to decompose the rays of light.

Decomposition of Light.—White light, as emitted from the sun, or other luminous body, is found to be composed of seven different kinds of light; namely, *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet;* and this compound substance may be decomposed or separated into its elementary parts.

Fig. 27, represents a prism, so placed, that a beam of light, admitted by a small aperture, A, falls upon it, and being refracted is thrown upon the screen B C, forming an oblong image called the *prismatic spectrum*, containing the seven colours already named.

The Rainbow is formed by the sun's rays falling upon the upper parts of the drops of rain, and being then, by refraction, thrown on another part of the same drop, where they are again refracted and reflected to the eye, so as to produce the successive colours from the upper part of red, orange, yellow, green, blue, indigo, and violet (fig. 28).

The Eye—Vision.—Figs. 29 and 30 represent a front view and a section of the eye. The eye is composed of three coats or skins, one covering the other. Within the coverings of the eye-ball are contained three transparent substances, called *humours*. These different humours form a compound lens, which refracts the rays of light rebounding from objects, forming an image of them upon the retina, the sensation being transmitted by the optic nerve to the brain.

Telescopes.—Fig. 31 illustrates the construction and action of a refracting telescope, and fig. 32, that of a reflecting telescope. The lines show the direction in which the rays are transmitted through the various lenses.

Fig. 33 represents the *camera obscura*. This interesting optical instrument consists of a convex lens A, through which the rays of any objects are admitted into a darkened chamber, where they fall on a plane mirror B, placed at an angle of forty-five degrees; by this they are reflected upwards against a plate of ground glass C, upon the upper surface of which the objects appear in their natural colours

Fig. 34 represents that well known instrument, the *magic lantern.*

ELECTRICITY.

Electricity is the operation of a subtile fluid, generally invisible, which appears to be dlffused through most bodies.

If a stick of sealing-wax or a watch-glass be rubbed upon a dry piece of woollen cloth, it will be found, while warm by the friction, that they have acquired the property of attracting small light bodies, as feathers, &c. Some of these will adhere to the surface of the wax or glass, and others will be thrown off from the body, as if they were repelled from it. This phenomenon may be strikingly exemplified by the small apparatus represented at fig. 1. A, is a stand with a bent wire, to which, at the hook, B, a fine silk thread is attached, having at its extremity a small pith ball, C. If the glass rod, D, be rubbed and presented to the ball, this will be immediately attracted to the glass, and will remain in contact with it for a few seconds; if the glass be now withdrawn, and again presented to the ball, the latter will be repelled (fig. 2). If, instead of the glass, a piece of sealing-wax, rubbed in the same way, be employed, the same effect is produced. Both these electrics have, therefore, in the first place, the power of *attracting* another body before they have communicated to it any of their own electricity; and, secondly, having communicated a portion of their electricity, they *repel* it. But a very remarkable circumstance takes place, if we, after having conveyed electricity to the ball, C, by means of excited glass, should present to it, after the former was withdrawn, excited sealing-wax: the ball, instead of being *repelled*, as it would be were the ball again applied, is *attracted* by the wax. If the experiment be reversed, and the excited wax first presented to the ball, and then the excited glass, the latter will be found to repel the ball. Hence, we conclude, that there are two opposite electricities; namely, that produced by excited glass, to which the name of *vitreous*, or *positive* electricity, has been given, and that produced by excited wax, to which the name of *resinous*, or *negative* electricity, has been given.

Fig. 3 represents the *Cylindrical Electrical Machine*, consisting of a hollow cylinder of polished glass, C C, revolving upon an axis. Two hollow metallic conductors, D E, are placed parallel to the cylinder on each side, upon two insulated pillars of glass. To one of these conductors, E, a cushion is attached, and held close to the cylinder; from the upper edge of the cushion there proceeds a flap of oiled silk, which extends over the upper surface of the cylinder to within an inch of a row of metallic points, proceeding from a hollow rod fixed to the side of the opposite conductor. When the cylinder is driven round by the handle, the friction of the cushion upon it produces a transfer of the electric fluid from the latter to the former; that is, the cushion becomes negatively, and the glass positively, electrified. By the revolution of the cylinder, the fluid adhering to the glass is carried round, and its escape prevented by the silk flap, until it arrives near to the metallic points, which absorb most of the electricity, and convey it to the prime conductor, D, which thus becomes positively electrified, while the other conductor, having parted with this electricity, is negatively electrified.

Fig. 4 represents the *Plate Electrical Machine*. The plate is turned by the handle through the rubber, which is coated with a metallic amalgam, and diffuses the excitement over the glass, the points carrying off a constant stream of positive electricity to the prime conductor, upon the principle already described.

Fig. 5 represents the *Hydro-Electric Machine*, an apparatus of recent date and construction, and of immense power. It consists of a steam boiler, A, insulated on stout glass pillars. The steam is made to issue through a great number of bent iron tubes, B B, terminating in jets of wood. An insulated projecting conductor, C, is placed in connexion with the boiler, for the purpose of collecting the excited electricity; and another conductor, D, formed of a metallic case having several rows of points, is placed immediately in front of the jets, to receive and carry off the opposite electricity of the steam, and prevent its return to the boiler, by which the excited forces would be neutralized. The electricity thus produced is the result of the friction of condensed particles of water, whilst being driven by the still issuing steam through the jets, these watery particles, performing the office of the glass plate, or cylinder of the common machine, and giving out vitreous electricity. The wood jets and pipes act as the rubber, and give out resinous electricity.

ELECTRICITY.

Electricity can be transferred or communicated from one body to another. An electrified ball can be deprived of its electricity by being touched with a metallic rod, but if we touch it with glass or wax the electricity will remain unaffected. Hence, metals are said to be *conductors*, and glass and wax *non-conductors*. Bodies differ greatly in their power of conduction. A list of tbe principal substances that possess tbese properties will be found on the diagram. The most convenient mode of obtaining an accumulation of electricity, is by employing a cylindrical glass jar, coated within and without nearly to the top with tin-foil, and having a cover of baked wood incased with sealing-wax to exclude moisture and dirt. A metallic rod rising above tbe jar, and terminating in a brass nob, is made to descend through the cover and communicate with the interior coating. An apparatus of this kind is called a *Leyden jar*, and is represented at fig. 6.

Fig. 7 represents a discharging rod, for establishing a communication between the inner and outer coating of tbe jar. The handle is of glass, to prevent the operator from receiving the charge of the jar.

By uniting a sufficient number of jars, we are able to accumulate a large amount of electricity. Such a combination of jars is called an *Electrical Battery*, (fig. 8).

Fig. 9 represents an instrument called a *Universal Discharger*, which is used for passing charges tbrough any substance that may be laid on plate A.

Fig. 10 represents an *Electro-meter*, an instrument used to detect the presence of electricity. If charged, either by placing the instrument on one of the conductors of a machine, or on the rod of an electrical jar, the reed rises and marks as an index on the graduated semicircle the angle of divergence, by which the comparative amount of electrification may be estimated. The hairs upon the well-known electrical toy, represented at fig. 11, are spread out, and stand on end upon the same principle.

Fig. 12 represents two bells suspended from a brass wire, D D, supported by a glass pillar, A. The electricity being conducted to the knob E, passes down the wires, D D, to the bells, which are then *positively* electrified, and attract the clappers, C C, that are negatively so, in consequence of being insulated by silken strings. Tbe clappers having become charged, strike against the centre bell to discharge themselves, and thus a peal is rung on the bells till the electricity is taken off.

Electric sparks are of a bluisb colour in the atmosphere in its ordinary state, and their character depends almost entirely on the form, area, and electrical intensity of the discharging surfaces. If the small ball, P (fig. 13), be attached to the prime conductor of a machine, and a larger ball, N, be presented to it, a series of brilliant sparks, of a crooked or zigzag form, will pass from the smaller to the larger ball. Wben, however, electricity is given off from short points, it is unaccompanied by noise, and presents tbe brusb-like appearance represented at fig. 14.

The influence of pointed conductors on electrically charged bodies, was first observed by Franklin, who showed that wben presented to them, their cbarges became silently and rapidly dissipated. Hence, the utility of pointed conductors to secure buildings from the effects of lightning (fig. 15).

Galvanism.—Tbe production of electricity in this case arises from the corroding action of an acid upon metallic surfaces. Tbe acid being interposed between two plates of dissimilar metals, usually copper and zinc, and the zinc being the more oxidable, gives out positive electricity. The two plates are connected together at the top by a wire, and this communciation establisbes what is called a voltaic or galvanic circuit; the electricity circulating round the zinc, wire, copper, and liquid (fig. 16).

There are many forms of galvanic batteries. Fig. 17, represents Daniell's battery, consisting of a cylinder of copper containing a porous tube, having a solid rod of amalgamated zinc in its centre. Fig. 18, represents Griffin's improved Smee's battery, consisting of six cells; the plates are arranged upon a frame suspended, by means of a rod and rocket wheel, over the trough containing the exciting liquid. By this arrangement any desired degree of power may be obtained by merely raising or depressing the frame.

MAGNETISM.

The theory of magnetism bears a very strong resemblance to that of electricity. Like it, magnetism has its attractions and repulsions, and it can be excited in one body and transferred to another, with, however, this striking peculiarity, that carbonized iron or steel, is nearly the only substance capable of exhibiting any strong indication of its presence. The *loadstone*, or natural magnet (fig. 1), is a hard, dark coloured mineral, found chiefly in iron mines; it is, however, seldom used, as its properties can be imparted to bars of steel, which may be made more powerful than itself.

Fig. 2 illustrates the polarity of the magnet. If a bar or needle, which has been rendered magnetic, be accurately poised on a point, one of its ends will point towards the north, and the other towards the south; hence, those parts of the magnet are termed the *north* and *south poles*.

The reciprocal attractions, repulsions, and neutralizations of the opposite magnetic forces may be illustrated by straining a piece of paper upon an open frame, and placing it over a bar magnet (N S, fig. 3). If some iron filings be now sifted upon the paper screen, the particles will arrange themselves in a series of curved lines, proceeding from similar points on each side of the middle of the bar; others will stand out at the extremities, as if repelled from the poles N S. If the *opposite* poles of two magnets be presented to each other, at about two inches distance, and iron dust be projected over them as before, similar results will ensue. Magnetic lines proceeding from similar points of each bar will appear uniting the two poles, as represented at fig. 4. If two *similar* poles be presented to each other, the lines of force mutually repelling each other, will present the appearance shown at fig. 5.

Fig. 6 represents the horse-shoe form of magnet, in which the two poles are brought near together, so as to attract a piece of iron by their combined force.

The earth itself is found to be a vast magnet, having its two magnetic poles situated in the neighbourhood of, but at some distance from, its poles of revolution. This is the reason why magnetized needles point in a north and south direction, not to the earth's axis (except at certain places), but to the magnetic poles. This will be seen by reference to fig. 7, which represents compass needles distributed over the globe, all lying in the direction of lines drawn from one magnetic pole to the other.

Fig. 8 represents the mariner's compass, the most essential part of which is a magnetized bar of steel, called the needle, accurately poised on a fine central point within a bowl or case, which is so supported as always to preserve a horizontal position. Upon the needle is placed the circular card represented at fig. 9, the ornamental point N being placed over the north pole of the needle, consequently the points round the circle indicate the cardinal and all intermediate points.

The inclination, or *dip* of the needle—that is, its deviation from the horizontal plane—affords a manifestation of the influence exercised upon it by the magnetism of the earth. Hence a dipping needle poised on a horizontal axis (as fig. 10), will, when carried to either of the earth's magnetic poles, stand *upright*, the end which is upward at one pole, being downward at the other. The further we recede from either pole, the less does the needle dip, as shown at fig. 11, where the dotted lines indicate the lines of equal dip, or parallels of *magnetic latitude*, and A and B, the north and south *magnetic* poles.

Electro Magnetism.—This department of science is founded on the connection ascertained to exist between electricity and magnetism. A (fig. 12) represents a bar of soft iron, bent into the horse-shoe form, around it is coiled a quantity of copper-wire covered with silk. The ends of the wire are connected with the poles of an active voltaic battery, the electricity from which passing along the coiled wire, converts the soft iron bar into a powerful *electro-magnet*, capable of sustaining, by its attractive force, a weight of many hundred pounds, and which it will continue to support so long as the connection with the battery is maintained, but the moment that connection is broken, the magnetic power of the iron ceases, and the weights fall.

The magnetic action circulates round the wire in two currents, moving in opposite directions, as represented at fig. 13. The wire being electric along its length and magnetic across.

Fig. 14, illustrates the action of electric currents upon a magnetic needle. A A, is a coil of copper wire, B, a magnetic needle freely poised, and pointing north and south. If the wire, C, be connected with the copper pole, and the wire, D, with the zinc pole, of an active voltaic battery, the needle will turn eastward, and upon reversing the wires, the needle will turn westward. Upon this simple principle depends the action of that astonishing apparatus the Electric Telegraph, of which our limits will only allow a brief description.

Fig. 15, represents a front view of the Telegraph instrument in which two needles are employed. Upon the dial plate are arranged certain letters, figures, and conventional signs. At the top of the instrument, within an ornamental case, is placed a bell or alarum to call attention to the instrument when a communication is about to be made. The alarum is put in action by a current of electricity being passed through a coil of wire encircling a piece of soft iron, which is thus converted into an electro-magnet, and attracts a lever, by which clock-work is set in motion, and the hammer caused to strike the alarum.

Fig. 16, represents the internal mechanism for moving each needle. The handle shown on the front of the instrument is attached to and works the cylinder A. This cylinder has its two ends capped with brass and insulated from each other by a belt of wood B; from the under part of one end projects a steel pin, C, and from the upper part of the other end, a similar pin, Z, these pins representing the copper and zinc poles of the battery with which they are in connection. In giving a signal, the handle is turned either to the right or left according to the direction the needle is required to take. Thus, by turning the cylinder so as to press the pin, Z, against the spring D, separating the latter from the point on the brass rod, E, the pin, C, is brought into contact with the boss, F. The electric current now passes from the pin, C, by the boss and metallic conductor through the wire coils, deflects the needle, and passing from the terminal, H, to the line wire it similarly deflects the needles of all the instruments in connection, and, being conducted at the extremity of the line to a plate of metal buried in the ground, it is transmitted by the earth to the terminal, G, and by the conductor and spring, D, to the pin Z. By reversing the movement of the cylinder the direction of the current is also reversed, and the needles are deflected in the opposite direction.

Magneto-Electricity.—As magnetism is derived from electricity, so electricity may be obtained from magnetism. If a piece of soft iron, A A, fig. 17, encircled by coils of copper wire be brought into, or removed from contact with the poles of a magnet, B B, electrical currents of a considerable magnitude are produced in the wire, and sparks will pass between the ends of the wire, P and N. To produce the effect, it is essential that the magnet be in motion, or that the conductor be in motion across the magnet.

CHEMISTRY.

The material world immediately within our observation is found to consist of fifty-five simple or elementary substances, which having hitherto resisted all endeavours to divide them into any others, are termed *elements of matter.* They are arranged into two grand divisions, under the names of non-metallic and metallic elements, (see Diagram).

Non-Metallic Elements. OXYGEN. This is a permanently elastic gas, colourless, destitute of taste and smell, and is the chief support of life and heat. It is one of the most important agents in nature. It forms 85 per cent. of water, one-fifth of air, and about one-half of all earthy matters. Its basis gives the acid character to all mineral and vegetable salts.

Oxygen may be procured by placing in a glass retort (A, fig. 1) some chlorate of potash, and on applying the heat of a spirit lamp, the gas will be given off, and being conducted by the tube B, will rise in the glass jar C, inverted in the pneumatic trough D.

NITROGEN or AZOTE, is a substance generally diffused throughout nature, and particularly in animal bodies. This gas is elastic, transparent, colourless, and inodourous; it destroys animal life, and a burning taper immersed in it is instantly extinguished. Four parts of nitrogen and one of oxygen constitute atmospheric air. Nitrogen acts in the atmosphere as a damper, preventing combustion and respiration from going on too fast.

HYDROGEN. This gas is the lightest body with which we are acquainted, being nearly fourteen and a half times lighter than the air. It forms one of the constituent parts of water, which is composed of eighty-five parts by weight of oxygen, and fifteen of hydrogen. Hydrogen will not support combustion, but is itself remarkably combustible.

CHLORINE. This gas is of a greenish colour, of a strong suffocating smell, and astringent taste. If breathed undiluted it destroys life, but it supports combustion. Its most essential property, however, is its power of destroying vegetable colours. IODINE and BROMINE much resemble chlorine in their properties.

FLUORINE. This substance is obtained from fluor, or Derbyshire spar. Combined with sulphuric acid, it forms an intensely active fluid, named hydro-fluoric acid.

CARBON. This is another simple substance extensively diffused throughout nature. It is found pure and solid only in the diamond; but may be obtained in the state of charcoal by burning wood in a close vessel or covered with sand. Carbon enters into the composition of bitumen and coal, and of most animal and some mineral substances. It forms nearly the whole of the solid basis of all vegetables, from the most delicate flower to the stately oak. It combines with all the supporters of combustion; and with oxygen forms carbonic acid. CARBURETTED HYDROGEN is a compound of carbon and hydrogen, which, mixed with oxygen, or sufficient air, forms an explosive mixture, whioh takes fire on the application of naked flame. In coal mines this gas was very destructive to human life until Sir H. Davy discovered that if the flame of the miner was surrounded by wire gauze, no explosion took place, hence his invention of the safety lamp, (fig. 2).

SULPHUR. This is a simple substance, the appearance of which is well known. It is inflammable, burning slowly with a pale blue flame, emitting strong suffocating fumes, which, when collected, form sulphuric acid.

SILENIUM is a substance nearly allied to sulphur in its nature; it melts at 212°, and on cooling becomes solid, having a metallic lustre; it is soft and easily reduced to powder. BORON is an opaque brownish powder, which is infusible. At about 600° it takes fire, and combines with oxygen, forming boraic acid. SILICON is a brownish coloured powder, and is very similar to boron in its appearance and relations to other matter. It can be exposed to a very high temperature without being fused.

PHOSPHOROUS. This is another simple combustible substance, but which is never found in a pure state in nature. It is commonly united to oxygen in the state of phosphoric acid, which is found in different animal, vegetable, and mineral substances. When pure it resembles bees-wax, and is so very combustible that it takes fire in the air, and appears luminous in the dark.

Metallic Elements. Metals, such as iron, copper, lead, &a., are familiarly known to every one, but there are many others which are very rarely to be met with. A list of the whole will be found npon the Diagram.

The following are some of the characters which distinguish metals from other

bodies. They all possess metallic lustre, they are mostly hard, heavy, and are all opaque; they are insoluble in water, admit of high polish, of being melted by heat, and of recovering their solidity by cooling. They are of different *colours;* some are white, as platinum, palladium, nickel, silver, tin, and mercury; some are bluish-white, as lead, zinc, iron, manganese, uranium, antimony; two are yellow, namely, gold and titanium; copper is red; bismuth, reddish; cobalt has a pale reddish tiut.

Caloric, or Heat. This element appears to to pervade the whole system of nature. It is called *sensible* caloric, when it produces the sensation of heat; and *latent* caloric, when it forms an insensible part of the substance of bodies. All bodies, with very few exceptions, are capable of expansion by heat; the gases to the greatest extent, liquids less so, and solids least. The expansion of fluids may be illustrated by the Thermometer, (fig. 3); the mercury in the bulb of which expands by the application of heat, and rises in the tube in proportion to the heat applied. Fig. 4 represents the Air Thermometer, consisting of a tube with a bulb containing air. The bulb beneath contains a coloured liquid, and if a portion of the air in the bulb be expelled by heat, it will, on cooling, reascend the tube, and indicate changes in the temperature by the rise or fall of the coloured liquid.

The Double Air, or Differential Thermometer, (fig. 5) is a modification of the preceding. To one of the limbs of the tube is affixed a scale divided into degrees. If one of its balls be more heated than the other, the unequal expansion of the included air puts the coloured fluid in motion, and indicates the increase of temperature.

Fig. 6 represents the Pyrometer, an apparatus for measuring the expansion of solid bodies. The metal rod A being heated by the flames, expands in length, and pressing against the wheel B, turns it, and the index marks the degree of expansion.

When fluids are subjected to a greater pressure than that of the atmosphere, they require a greater quantity of heat to make them boil. This fact is illustrated by the apparatus, fig. 7. Into the hollow globe A is first poured some quicksilver, into which the end of the tube B is immersed. The globe is then half filled with water, and the stop-cock being closed, and heat applied, the temperature soon rises above the boiling point, as indicated by the thermometer C inserted into the boiler. When the heat arrives at 218 degrees, the mercury will be elevated to six inches in the tube by the elastic pressure of the steam, and gradually rising, at 242 degrees, the elasticity of the steam will balance a column of mercury thirty inches high, being equal to the pressure of one atmosphere.

All bodies do not radiate heat alike, for their surfaces have great power of promoting or retarding the motion of caloric. If a cubical canister A (fig. 8) four inches square, of polished tin, be filled with boiling water, and placed at three feet distance from a concave tin reflector B, which has the non-graduated ray of a differential thermometer, C, in the focus, the quantity of radiated caloric will be denoted by the rising of the fluid in the graduated ray to 120 degrees. But if the canister be brushed over with a mixture of size and lamp-black, the thermometer will rise to 200 degrees. If a frame, D, having gold leaf over its centre be placed between the canister aud the reflector, the whole of the heat will be intercepted by this thin metallic substance, and no effect will be produced upon the thermometer.

Fig. 9, represents the Blow-Pipe, by which the flame of a caudle is made to produce an intense heat.

Fig 10 represents the Alcohol Blow-Pipe. The alcohol in the globe being boiled and converted into vapour by the heat of the flame beneath, and the vapour being made to issue out at the jet against the flame, causes a stream of the most intense heat to play upon any substance submitted to its action.

Fig. 11 represents a Still. Distillation is that process by which the volatile particles of a body or fluid are vapourized, condeused, and collected in appropriate vessels. The substance is exposed to such a heat as causes it to assume the gaseous form, in which state it is conducted by a worm tube through a vessel of cold water, by which it is condensed into a liquid state, and runs out at the extremity of the tube.

Fig. 12 represents Papin's Digester, which is constructed on the principle of mechanical pressure being necessary to elevate fluids to a higher temperature than those of commou boiling points.

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PROPERTIES OF BODIES.

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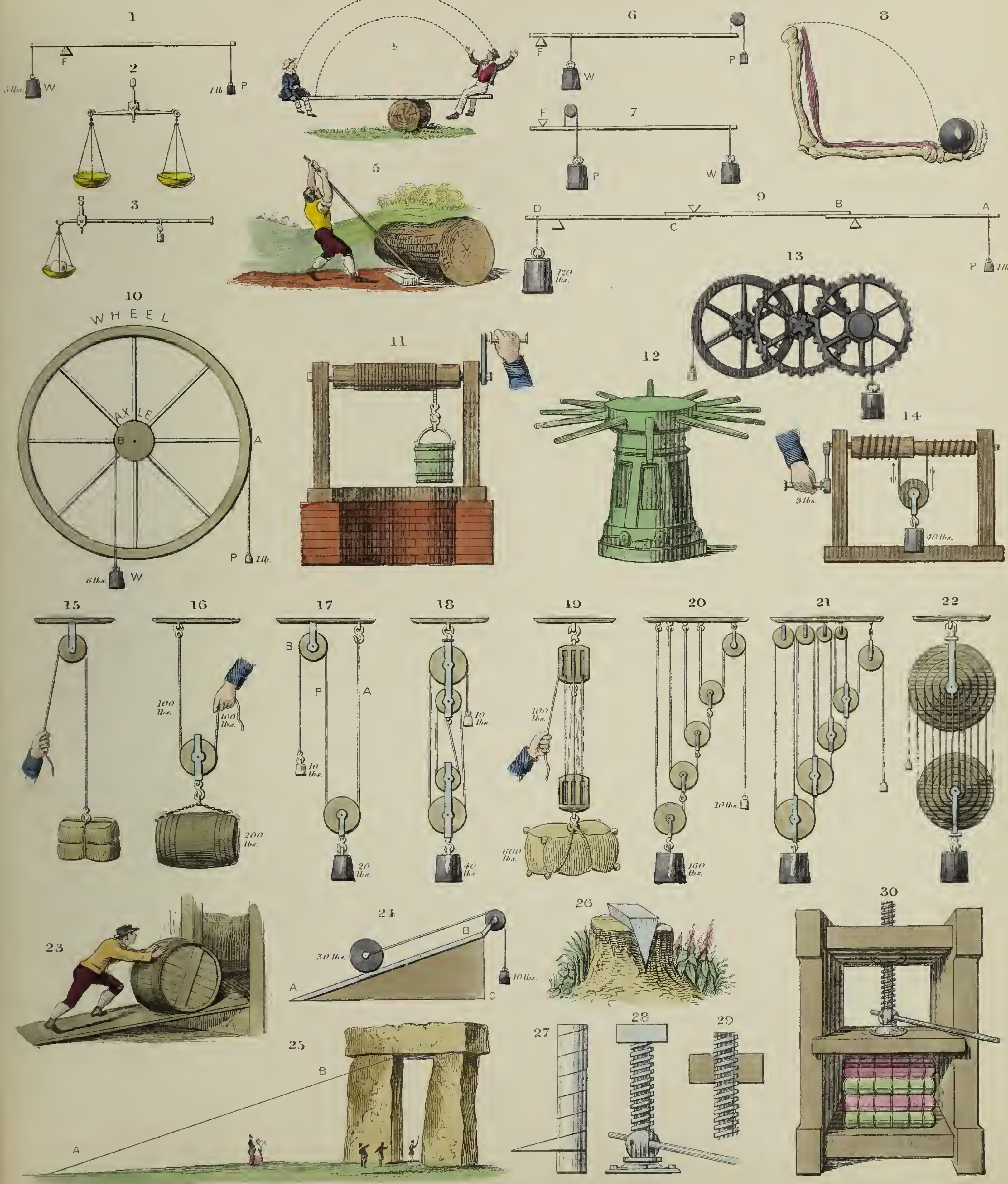

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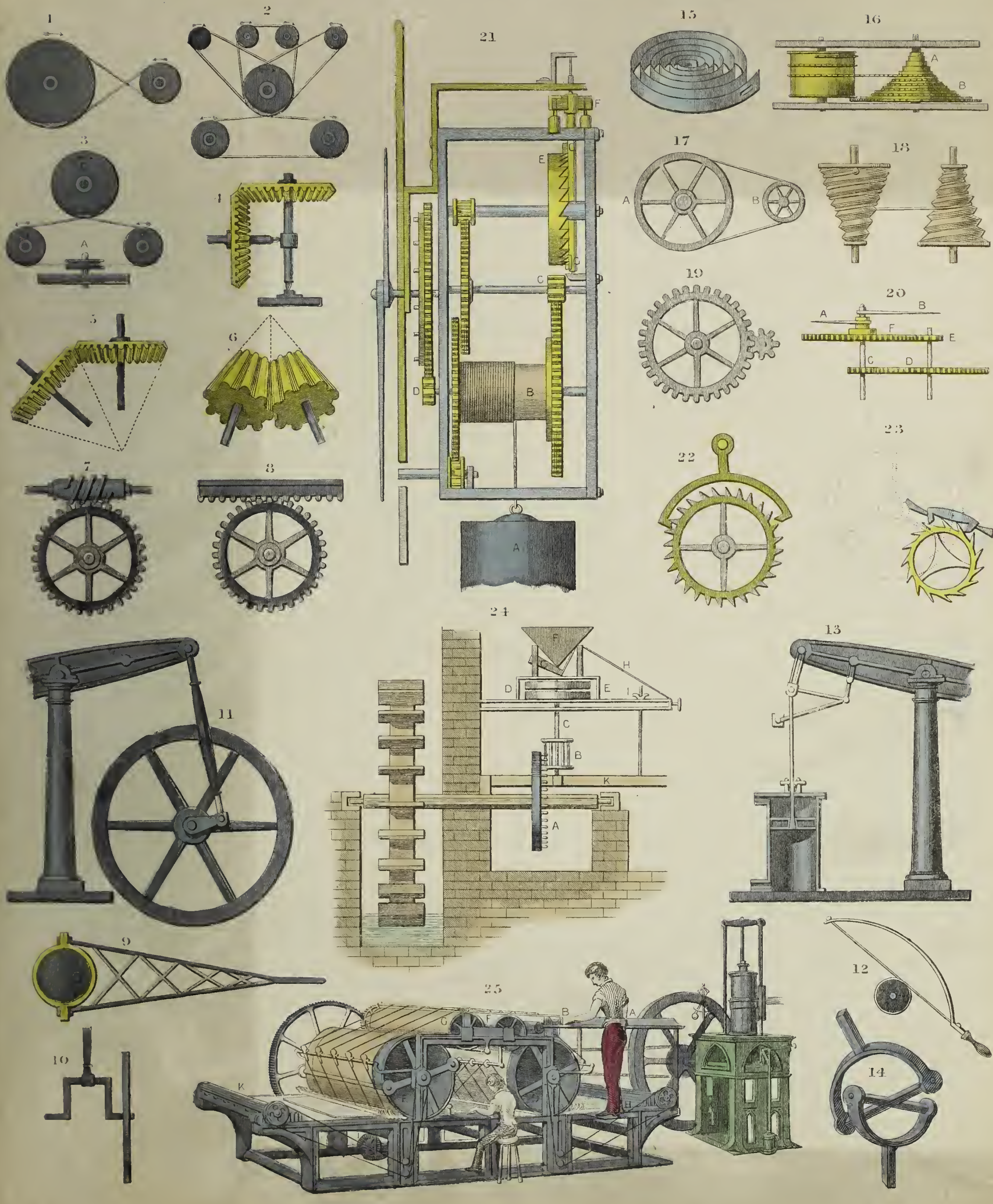

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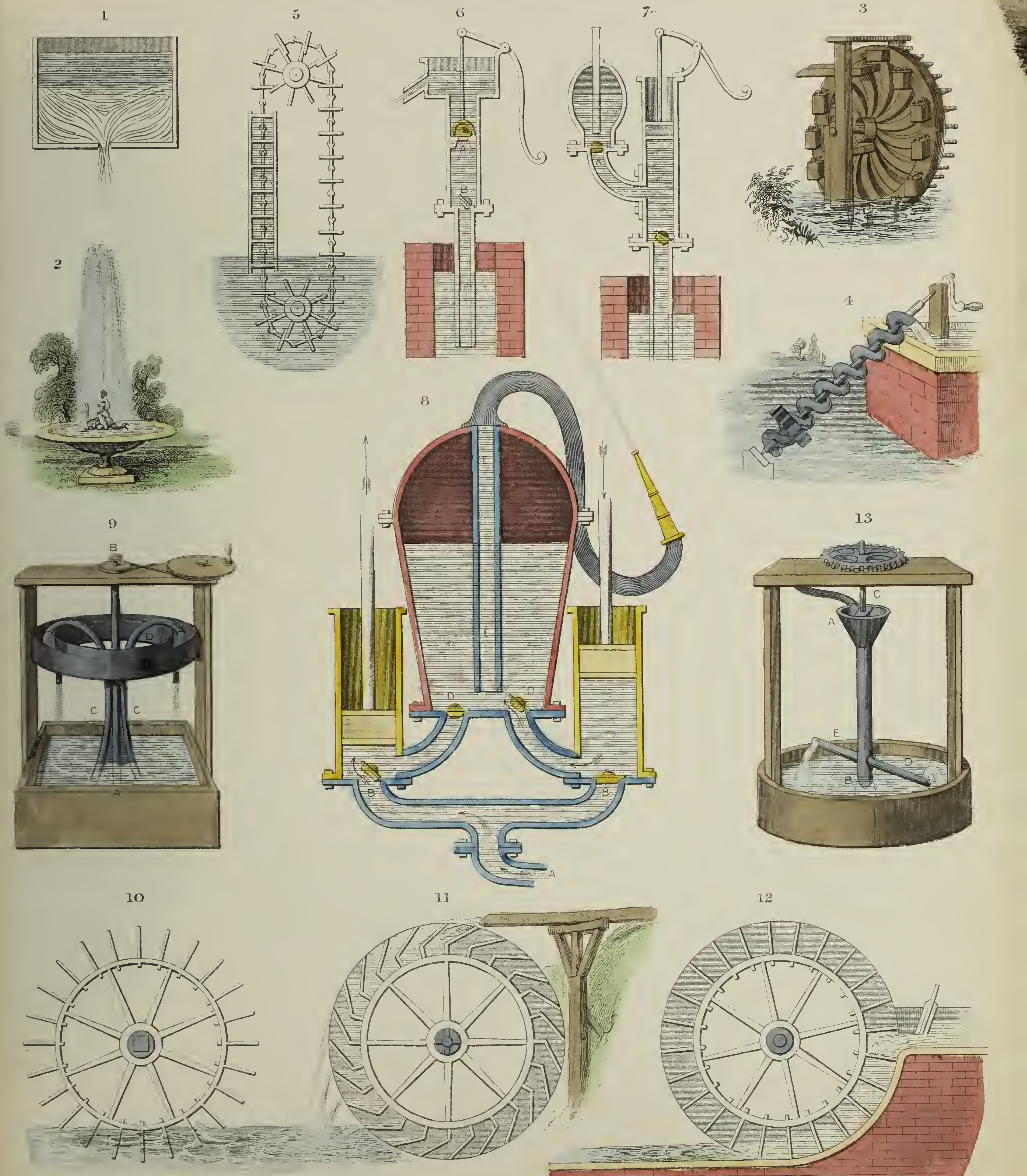

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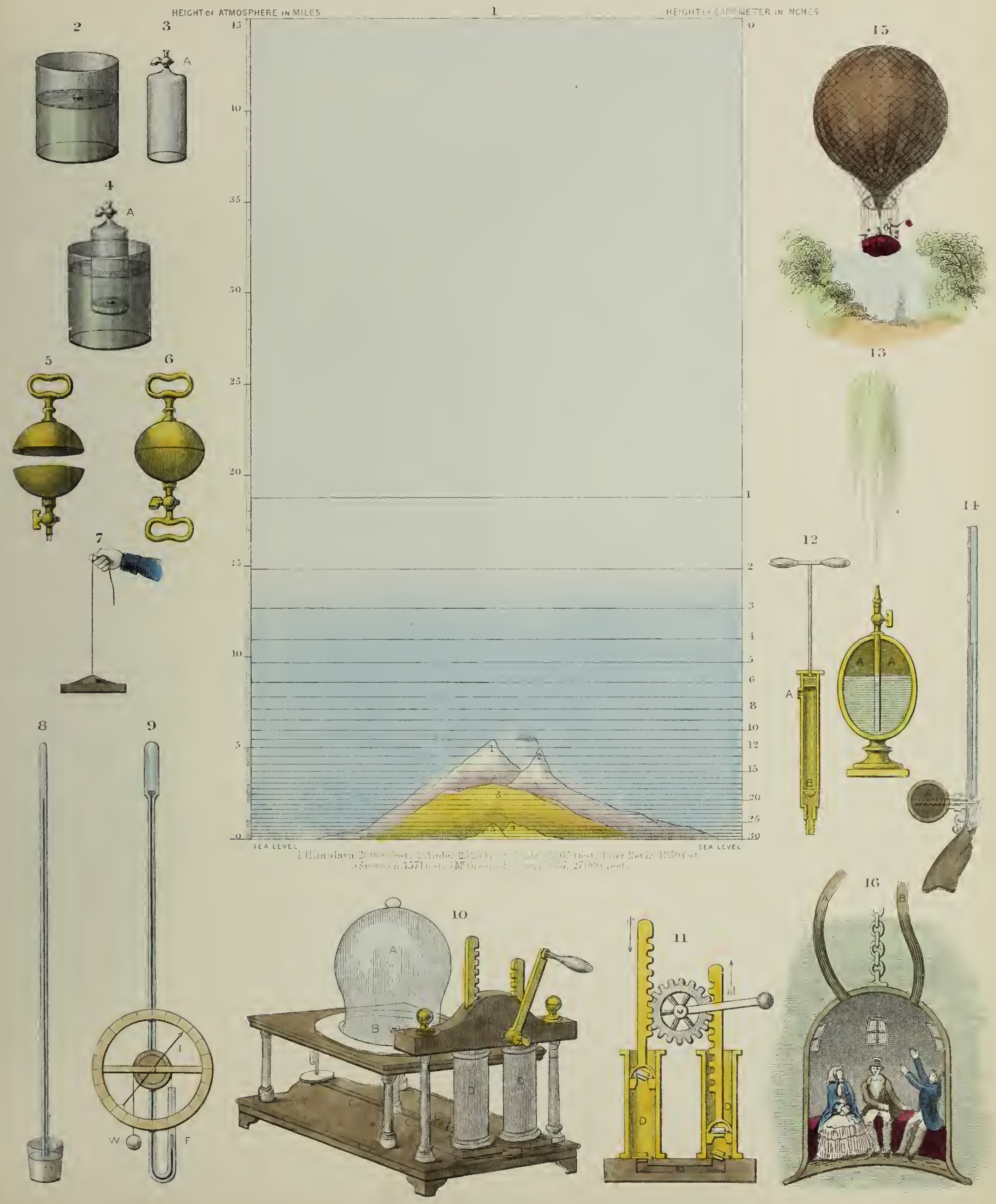

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ELECTRICITY.

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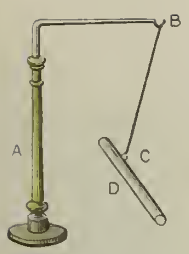

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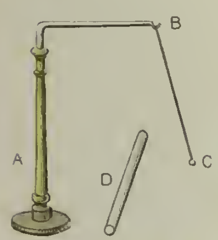

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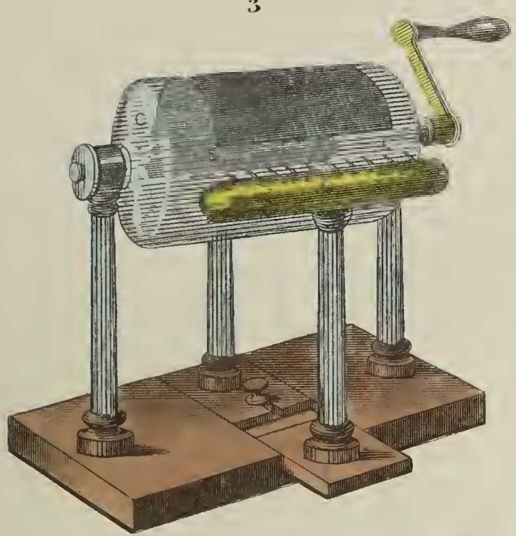

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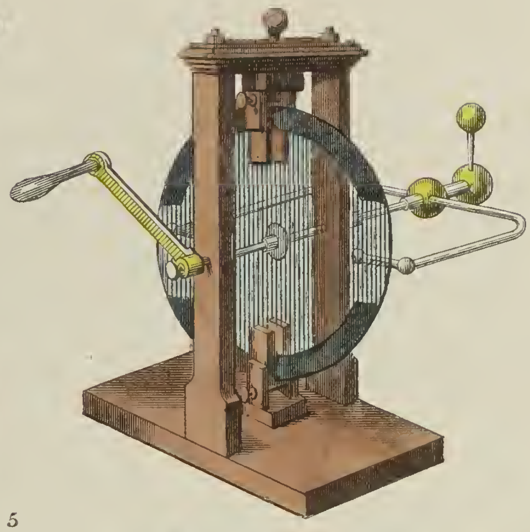

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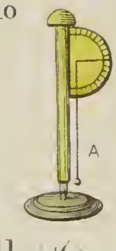

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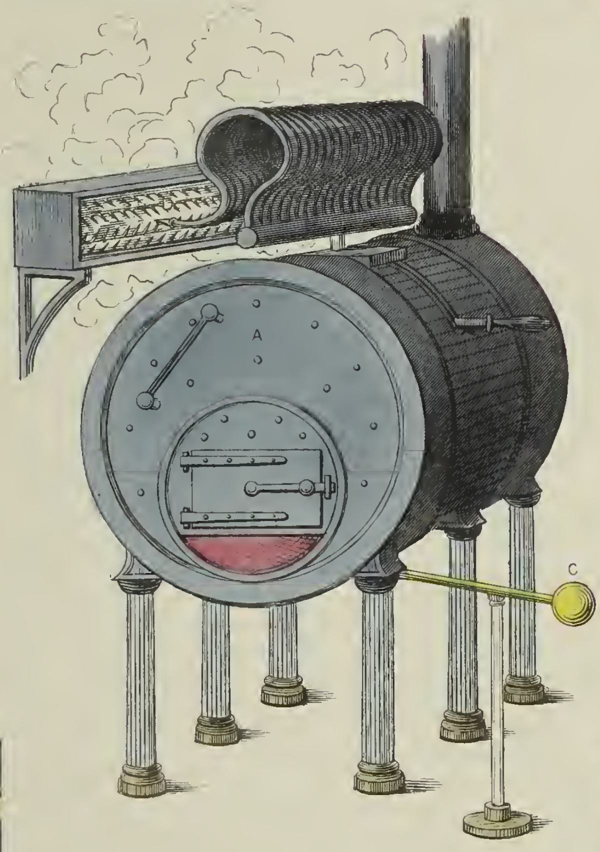

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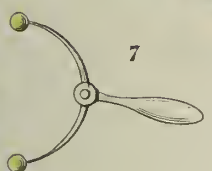

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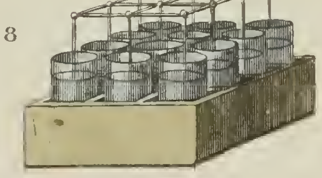


CONDUCTORS

Arranged in order of their Conductibility

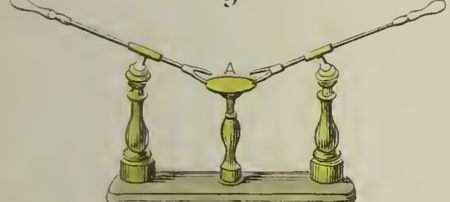
Silver, Copper, Lead, Gold, Brass, Zinc, Tin, Platina, Palladium, Iron, & Metals in General, Charcoal, Plumbago, Concentrated-Acids, Diluted-Acids, Saline Solutions, Metallic Ores, Animal-Fluids, Water, Living Animals & Vegetables Flame, Soluble-Salts, Alcohol, Moist-Earths.

NON CONDUCTORS

Arranged in order of their non conductibility

Shell lac, Amber, Resins, Sulphur, Wax, Glass, Various Minerals, Silk, Wool, Hair, Feathers, Leather, Air, & all Dry Gases, Baked Wood, Dry Vegetable Bodies, Porcelain, Camphor, Caoutchouc, Dry Chalk, Lime, Phosphorus, Ashes of Animal and Vegetable Bodies, Oils.

9



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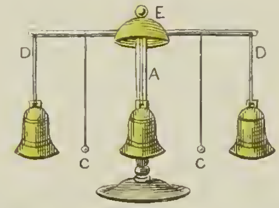

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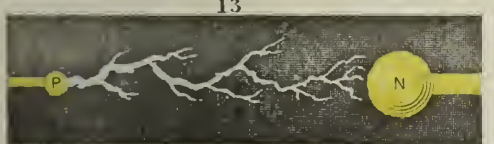

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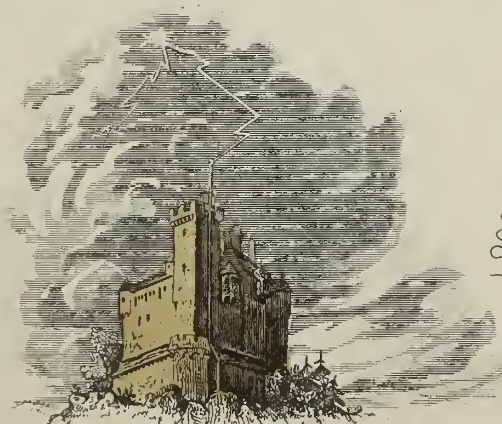

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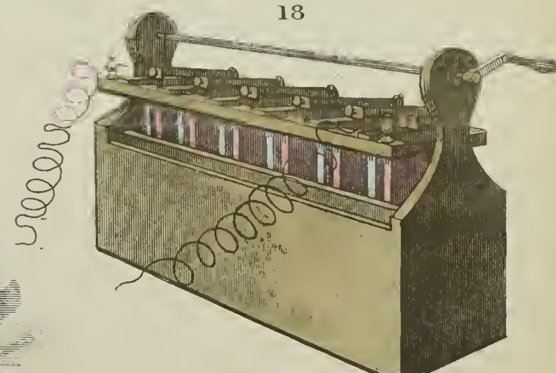

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MAGNETISM

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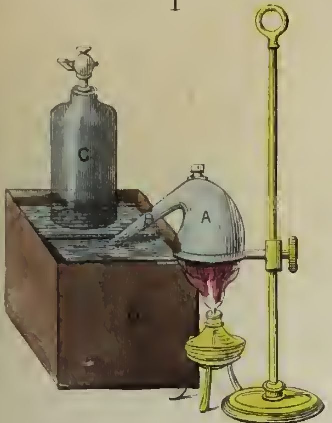
ILLUSTRATIONS OF NATURAL PHILOSOPHY

CHEMISTRY.

1



12

TABLE OF THE ELEMENTS OF MATTER

NON METALLIC ELEMENTS.

GAZOLITES.

(bodies permanently gaseous.)

Oxygen, Nytrogen, Hydrogen.

HALOGENS.

(bodies which produce Salts when in union with the metals.)

Chlorine, Iodine, Bromine, Fluorine.

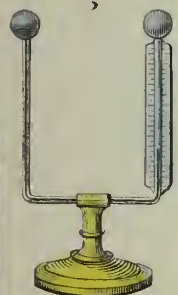
METALLOIDS.

(bodies resembling metals in their chemical relations.)

Carbon, Boron, Silicon, Sulphur, Selenium, Phosphorus

Oxygen, Chlorine, Bromine, Iodine and Fluorine having a tendency to combine with almost all other substances, and their union being generally accompanied by light and heat, have hence been termed Supporters of Combustion.

5



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METALLIC ELEMENTS.

I

BASES OF THE EARTHS.

Alluminum, Thorium, Glucinium, Zirconium, Ittrium.

BASES OF THE ALKALINE EARTHS.

Calcium, Barium, Strontium, Magnesium.

BASES OF THE ALKALIES.

Potassium, Sodium, Lithium.

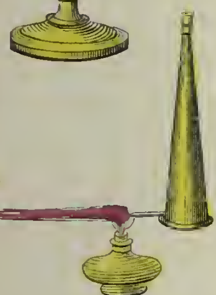
II

METALS WHICH DECOMPOSE WATER AT A RED HEAT.

Manganese, Zinc, Iron, Tin, Cadmium, Cobalt, Nickel.

METALS WHICH DO NOT DECOMPOSE WATER BY HEAT ALONE.

Arsenic, Antimony, Tellurium, Chromium, Vanadium, Uranium, Molybdenium, Tungsten, Columbrium, Titanium, Cerium, Bismuth, Lead, Didymium, Lantanium, Copper.



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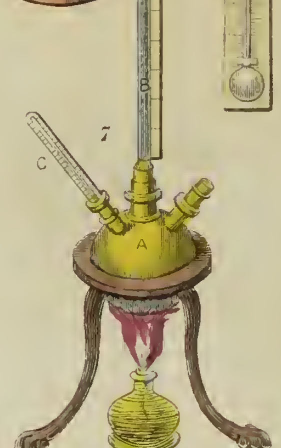

METALS WHOSE OXIDES ARE REDUCED BY A RED HEAT.

Gold, Silver, Mercury, Palladium, Rhodium, Platinum, Osmium, Iridium.

The above 55 Substances comprise the whole of the elements of matter, at present known.

10

Chemists have arranged the several forms of matter into the four following classes.

SOLIDS.

Which form the principal parts of the Globe, and differ from each other in hardness colour, density, &c.

FLUIDS.

As Water, Oil, &c. whose parts possess freedom of motion, and are generally non-elastic.

GASES

Whose parts are highly moveable, elastic, transparent, varying in colour and greatly in density.

ETHEREAL SUBSTANCES

Known to us only by their motion, when acting upon our organs of sense, and which are not susceptible of being confined. Such are the rays of light, and radient heat.

11

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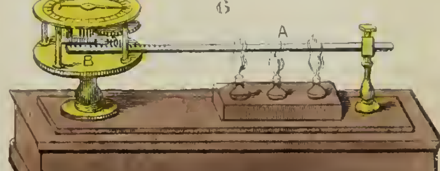

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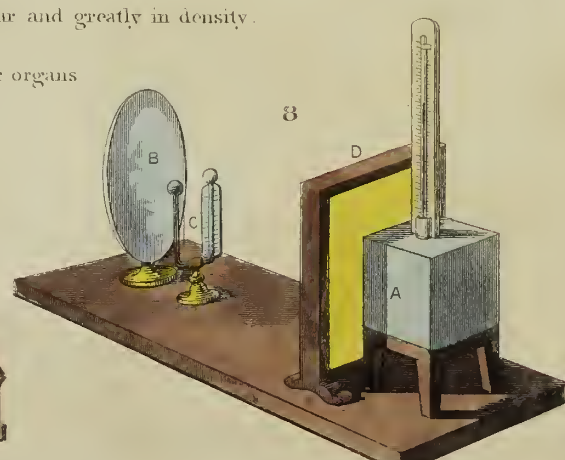

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